Framework for Evaluating the Indirect Benefits of Distributed Energy

David Lewis, BCS, Incorporated
William T. Choate, BCS, Incorporated
David Bartley, BCS, Incorporated
Kenneth Green, BCS, Incorporated

ABSTRACT

This paper describes work designed to develop a common set of value measurements for the indirect benefits of distributed energy (DE). Indirect benefits are the values of DE that are not included in the delivered price of electricity. A full analysis of DE technologies must include the indirect benefits of DE as these benefits provide additional value to the user and society. The development of a "framework" for evaluating the indirect benefits of DE is described in this paper, and the results of the initial analysis and next steps are presented.

Introduction

This paper describes work designed to develop a common set of value measurements for the indirect benefits of distributed energy (DE). This work was performed under contract to the U.S. Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy (EERE), Office of Distributed Energy and Electricity Reliability (DEER). Indirect benefits are the values of DE that are not included in the delivered price of electricity. Exhibit 1 at the bottom of this page includes further definitions. A full analysis of DE technologies must include the indirect benefits of DE as these benefits provide additional value to the user and society.

The results of the work are described in a study titled "Framework for Evaluating the Indirect Benefits of Distributed Energy," available at www.bcs-hq.com/der/indirect (BCS, 2003). (BCS, 2003) The Framework study identifies sources that provide quantitative and qualitative value measurements, presents those values, and references them to allow analysts to identify the assumptions used to define the studies that led to the values.

DE provides many direct benefits, including improved generation and transmission reliability, reduced system planning costs, reduced capital costs, and reduced operation and maintenance costs. The magnitude of these benefits is variable because the magnitude is influenced by many site-specific and regional factors. The direct nature of these benefits means that their values can be included in the delivered cost of electricity. Direct benefits are well documented and understood.

Exhibit 1. Definitions

Value – combination of benefits and displaced cost.
Indirect Benefit – value is not traditionally included in the delivered price of electricity.
Direct Benefit – value is included in the delivered cost of electricity.

The studies identified through this analysis show that the full value of DE includes many indirect benefits that are not traditionally included in the delivered price of electricity. These indirect benefits, also called external, or non-energy benefits, must be counted in order to accurately gauge the full value of DE technologies. The areas of indirect benefit covered in the framework include business, ecosystem, human health, human welfare, and national security benefits.

BCS, Incorporated (BCS) is currently using these data to identify "best estimates" of the indirect benefits of DE. Combined, these two pieces of work will provide information to assist in evaluating the full value (combination of direct and indirect value) of DE technologies.

Approach

The approach to this analytical work includes two studies. The first is titled "Framework for Evaluating the Indirect Benefits of Distributed Energy" (Framework study). The second is titled "Best Estimates for the Indirect Benefits of Distributed Energy" (Best Estimates).

The approach used to develop a framework for evaluating and estimating the value of indirect DE benefits included:

- Identifying available analyses related to quantifying the indirect benefits of energy systems,
- Categorizing analyses by type of benefit covered,
- Ranking sources to establish their usefulness to the report,
- Distilling the quantitative data from those sources, and
- Presenting the results in a format that can be easily updated, commented on, and improved.

The Best Estimates work is currently underway. BCS is using the data ranges developed in the Framework study to identify estimated values for DE related impacts. The approach used to develop the Best Estimates will include:

- Evaluating each data range and the assumptions used in its development,
- Collecting additional data where needed,
- Developing an individual methodology for estimating each impact, and
- Identifying a more focused total value range including a best estimate.

Indirect Benefits Valuation Framework

Goals

The goals of the Framework are to:

- Build a reference frame to which new information can be easily added,
- Identify estimates of values for indirect DE benefits from literature sources,

- Provide analysts with references to promote further analysis of the values presented, and
- Assist in assigning a more complete value to the R&D portfolios of the DOE, EERE, DEER.

Methodology

The approach did not include an assessment of the validity of the assumptions, site-specific factors, or other complexities of the individual studies. Instead, it relied on systematic source and data referencing, and minimal data manipulation to allow analysts to refer back to the original document and assess values for their particular analyses. In addition, it provided a solid beginning to the next analytical step, development of Best Estimates. The Best Estimates analysis is described in Section IV of this paper.

Further analysis through the best estimates is necessary because most of the data identified involve analysis of the impacts of pollutants associated with the production of electricity. They do not associate these impacts with electricity production. The impacts identified in the sources must be correlated to electricity production and then to DE by measuring unit impacts and identifying unit production of pollutants by traditional electricity generation versus DE.

Source and data collection. In total, 154 documents were collected, reviewed, and entered into a database to facilitate sorting and future analysis. The initial document collection was identified by a "working group" of staff from DOE. This group included John Atcheson, David Bassett, John Millhone, Richard Moore, Judy Odoulamy, Alan Schroeder, Phil Shambaugh, and Paul Trottier. The document they compiled was sent out for review to representatives from federal and state government, industry groups, environmental organizations, national laboratories, and others. These reviewers responded by supplying additional documents that would inform the effort to identify the indirect benefits of DE.

Using these review inputs, BCS developed a "Sources Summary" database to organize future document collection. For each document identified, BCS developed a source summary, including bibliographic information and a summary of the contents of the source. Additionally, in consultation with the Office of DEER, BCS categorized the documents and ranked them based on the methodology outlined in Section III.B.2. and III.B.3. of this paper. The database was used to generate a "Sources Summary" document. This document was again sent out for review to representatives from federal and state government, industry groups, environmental organizations, national laboratories, and others. After incorporation of this input, the "Sources Summary" database was updated and included in the Framework study. The scope of the Framework study was to collect existing sources based on input from DOE and the interested experts; a comprehensive literature search was not conducted, and additional sources may still be identified.

Categorization of impacts. Each literature source was assigned a primary impact category and a primary impact subcategory. The categories and subcategories are intended to improve the ease of the source review. Categories and subcategories are listed in Exhibit 2. Many documents cover more than one category and subcategory. To deal with these cases, a cross-reference system was developed. Each source summary in Appendix B of the Framework study, and in the on-line database, has a primary category and primary subcategory. Each

source summary also includes a cross-reference list of each additional subcategory to which the document is relevant.

The DOE "working group" that initiated this report identified the categories, choosing those that represent the scope of indirect values associated with DE. The categories are flexible; they may be updated as this analysis evolves. The category assignments are based on an evaluation of the impacts that each literature source measures. In addition, many categories include the subcategory "Broad Study." The "Broad Study" subcategory is used for documents that cover too many impact areas to fit into one subcategory.

Exhibit 2. Impact Categories

Category	Subcategory
Business Impacts	Broad Study
	Crop Impacts
	Power Quality
	Reliability
	Risk and Insurance
National Security	Electrical System Resiliency
	Fuel Security
	Nuclear Security
Ecosystem	Broad Study
	Extraction and Transport of Fuel
	Global Warming
	Silviculture Impacts
	Species Diversity
	Water Quality Impacts
Human Health	Broad Study
	Carbon Dioxide
	Carbon Monoxide
	Lead
	Mercury
	Nitrogen Oxides
	Ozone
	Particulate Matter
	Sulfur Oxides
	Volatile Organic Compounds
Human Welfare	Broad Study
	Horticulture Damage
	Material Damage
	Regulation Costs
	Visibility Degradation

Issues with categorizing documents and comparing data. The issues involved with categorizing documents and comparing data include:

- Most studies are not strictly defined by a single impact,
- Studies use different units of measure,
- Studies begin with different sets of assumptions,
- Study boundaries differ,
- Data is presented in disparate formats, and
- Estimates compiled are interrelated, using overlapping and duplicated data.

Indirect value estimates are highly variable, uncertain, and cannot be easily compared. Therefore, the Framework Study provides ranges of values wherever possible. The comparability issues associated with the data collected will be addressed in the "best estimates" phase of this study. The balance of evidence provided by these ranges demonstrates that DE applications offer valuable indirect benefits that are not reflected in the delivered price of electricity.

Ranking of sources. To identify documents with the most useful and well-researched data, BCS ranked each document in three areas as shown in Exhibit 3: Theory/Data; Supporting Documentation; and Peer Review. Although this report ranks the documents referenced, it has not used those rankings to weigh the values reported. Instead, rankings were chosen in order to provide an objective look at the documents and to facilitate further document selection and analysis.

Exhibit 3. Ranking

Area	Rank 1 - 3		
	1	2	3
Ideas And Theory	Only Theoretical or Idea Oriented Content	Some Physical Data	Extensive or Original Physical Data
Supporting Documentation	No Supporting Documentation	Some Supporting Documentation	Extensive Supporting Documentation
Peer Review	None	Unknown	Yes

Note: In some cases, ranking is not possible due to document availability. In those cases the term N/A is used.

- Theory/Data - Sources are graded on a scale from 1 to 3 based on whether they include: ideas and theory or physical data. Sources with original data provide better information for developing numeric baselines than sources that present only concepts. On this scale, a 1 is given to a document with only theoretical or idea-oriented content, 2 is assigned to a document with some physical data, a document with extensive or original physical data is given a 3.
- Supporting Documentation - Sources are ranked on a scale from 1 to 3 based on the amount of supporting documentation they contain. On this scale, 1 represents a document with no supporting documentation, 2 indicates a document with some supporting documentation, and 3 is given to a document with extensive supporting documentation.
- Peer Review - Sources are ranked on a scale from1 to 3 based on whether or not they have been peer reviewed. On this scale, 1 indicates a document that has not been peer reviewed, 2 identifies a document of unknown peer review status, and 3 denotes a document that has been peer reviewed.

Searchable internet database. One aspect of the study was the development of a searchable version of the documents used. This data is available on the Web at www.bcs-hq.com/der/indirect. The intent of the on-line availability of the data behind the report is threefold: first, to enable further analysis on this issue; second, to continually improve the content of the derived data; and third, to ensure the transparency of assumptions in each referenced document.

Pacing the complete source reference on-line allows other analysts to use the data collected in this report with references to the original source. The second reason for posting the results of this analysis on-line is to continually improve the baseline data. Interested parties may submit additional documents, or comment on the analysis and documents currently contained in the Framework. The set of documents collected at this point is not comprehensive. Adding input from additional specialists will increase the applicability and precision of the data developed from the literature. The third reason for posting the results of this analysis on-line is to ensure that the assumptions of the data presented in the Framework study are fully transparent. Rather than analyzing the assumptions in each study, the Framework study relies on systematic source and data referencing and minimal data manipulation to allow analysts to refer back to the original document and assess it for their particular analyses.

Results of the Framework Study

In the Framework study, BCS evaluated the documents identified for each impact category and subcategory. Those that contain quantitative data were set aside for further analysis. The data demonstrate that the benefits provided by DE technologies do have positive indirect values. Further analysis will be required to:

- Determine what portion of the values identified in this report are applicable to DE;
- Narrow select values from the ranges identified;
- Identify existing values not included in this report; and
- Pursue values in areas for which no current value data exists.

Exhibit 4 outlines the number of sources identified in each impact category. Exhibit 5 provides a snapshot of the results found in the Sources Summary database. For individual subcategories the lowest and high value is provided. Data are only presented for values that are comparable based on their units of measure. For detailed information on each subcategory, refer to http://www.bcs-hq.com/der/indirect. A guide to Exhibit 5 is shown below.

Exhibit 4. Documents by Category

Category	Number of Documents	Documents Cross-Referenced to this Category
Business Impacts	38	23
National Security	14	9
Ecosystem	46	18
Human Health	44	33
Human Welfare	12	24
Total	154	

The conclusions reached by different studies vary greatly. Each study includes different classes of impacts. Even those that consider the same impacts may frame them in radically different ways and use different assumptions to define their analyses. Most of the analyses do not apply specifically to DE. In each case, before using the data identified in the

database, or in this report, readers should reference the original document to ensure they have a full understanding of the assumptions and scope of the referenced study.

Guide to Exhibit 5:

- **Category:** Each document has an assigned category, see Section III.B.2. for details.
- **Subcategory:** Each document has an assigned category, see Section III.B.2. for details.
- **Comparison Value:** For purposes of comparability, monetary estimates were converted to 2001 dollars. The figures shown in the comparison value column were calculated by converting the reported value to 2001 dollars using the Consumer Price Index.
- **Comparison Units:** To facilitate comparison of impact values, units of measurement were converted to comparable units whenever possible. For example, impacts reported in pounds were converted to tons.
- **Reported Values:** The value identified in the source document. See each document for details on how the number was developed.
- **Reported Units:** The unit identified in the source document. See each document for details on why that unit was selected.
- **Reported $ Year:** The dollar year used by the source document when reporting quantitative values.
- **Source:** Refers to the ID number used in the Framework Study and included in the database at www.bcs-hq.com/der/indirect.
- **Abbreviations:**
  - NA (Not Available) denotes cases in which quantitative data is not available.
  - NC (Not Comparable) denotes cases in which quantitative data is available, but could not be converted for comparison.
  - MMHA = Mortality, Morbidity, and Hospital Admissions

Exhibit 5. Ranges for Comparable Values (BCS, 2003, p.9)

Category	Subcategory	Comparison Value	Comparison Units	Reported Values	Reported Units	Reported $ Year	Source
Business Impacts	**Power Quality**	5.45	$billion/yr	5.13	$billion/yr	1999	ID-122, pg. 15
		435	$billion/yr	400	$billion/yr	1998	ID-122, pg. 15
	Reliability	41	$billion/yr	26	$billion/yr	1987	ID-122, pg. 15
		189	$billion/yr	150	$billion/yr	1992	ID-122, pg. 15
	Insurance	NA	NA	NA	NA	NA	NA
	Crop Impacts	3 - 8	$billion/yr	2 - 6	$billion/yr	1991	ID-29, pg. 19
		8	$billion/yr	6	$billion/yr	1990	ID-44, pg. 287
National Security	**Fuel Security**	21 - 77	$billion/yr	15 - 54	$billion/yr	1989	ID-54, pg. 1
	Electrical System Resiliency	NA	NA	NA	NA	NA	NA
	Nuclear Security	NA	NA	NA	NA	NA	NA
Ecosystem	**Extraction & Transport of Fuel**	NC	NC	NC	NC	NC	NC
	Global Warming	0.7	$billion/yr	0.5	$billion/yr	1991	ID-17, pg. 55
		148	$billion/yr	150	$billion/yr	2002	ID-155, pg. 4
	Water Quality Impacts	1 - 3.5	$billion/yr	1 - 2.7	$billion/yr	1991	ID-17, pg. 55
	Silviculture Impacts	0.3 - 3	$billion/yr	0.2 - 2	$billion/yr	1991	ID-17, pg. 55
	Species Diversity	NC	NC	NC	NC	NC	NC
Human Health	**Carbon Monoxide**	0.36	$/ton	0.29	$/ton	1993	ID-4, pg. 10
		1,277	$/ton	1,012	$/ton	1992	ID-03, pg. 72 (reference: ID-139)
	Lead	492	$/ton	401	$/ton	1993	ID-4, pg. 10
		4,048	$/ton	3,302	$/ton	1993	ID-4, pg. 10
	Mercury	35,600	$/ton	6.95	$/Kg	1995	ID-6, pg. 22
	Nitrogen Oxides	3.33	$/ton	2.64	$/ton	1992	ID-128, pg. 6
		372,060	$/ton	137.29	$/lb	1990	ID-01, pg. 25 (reference: ID-23)
	Ozone	36	$/ton	29	$/ton	1993	ID-4, pg. 10
		495	$/ton	404	$/ton	1993	ID-4, pg. 10
	Particulate Matter	81	$/ton	60	$/ton	1990	ID-14, pg. 2-3
		68,160	$/ton	25.15	$/lb	1990	ID-01, pg. 25 (reference: ID-23)
	Sulfur Oxides	No Value	$/ton	No Value	$/ton	1992	ID-03, pg. 72 (reference: ID-139)
		106,500	$/ton	39.30	$/lb	1990	ID-01, pg. 25 (reference: ID-23)
	Volatile Organic Compounds	1,277	$/ton	1,012	$/ton	1992	ID-03, pg. 72 (reference: ID-139)
		41,192	$/ton	30,400	$/ton	1990	ID-14, pg. 2-12
	Total Health Costs	33 - 610	$billion/yr	24 - 450	$billion/yr	1990	ID-29, pg. 19
		72 - 871	$billion/yr	55 - 670	$billion/yr	1991	ID-29, pg. 12
	MMHA	0.347 - 8.713	$billion/yr	189 - 4,748	$million/yr	1982	ID-14, pg. 2-8
Human Welfare	**Material Damage**	0.5 - 11	$billion/yr	0.4 - 8	$billion/yr	1990	ID-29, pg. 19
	Regulation Costs	NA	NA	NA	NA	NA	NA
	Visibility Degradation	7 - 50	$billion/yr	5 - 37	$billion/yr	1990	ID-29, pg. 19
	Horticulture Damage	NA	NA	NA	NA	NA	NA

The remainder of this section describes the results the Framework study by impact category. Most of the data collected relate to the overall impact of each subcategory on the U.S. economy. The data are still applicable to DE because DE has the potential to capture a portion of the dollar value identified.

Business impacts. This category includes businesses impacts such as: crop, insurance, power quality, and reliability. These subcategories were chosen because there are clear pathways for DE to provide value in each area. There is overlap between the values identified in this section and the values identified in other sections. For example, global warming has impacts on crops, and increased electrical system resiliency has impacts on electricity reliability.

Of the four business impact subcategories, crop, power quality, and reliability have documents with quantitative data, while insurance does not. The importance of the insurance benefits potentially provided by DE has only recently been recognized by the industry. Additional documents should become available in the near future. The ranges for power quality and reliability are effectively presented in "Scoping Study on Trends in the Economic Value of Electricity Reliability to the U.S. Economy." For example, in 2001 dollars, the power quality range is from $5.5 billion per year to $435 billion per year (Eto, Joseph, et al., 2001, p. 15).

National security. This category includes fuel security, electrical system resiliency, and nuclear security. Quantitative data in this section was available only for fuel security. Due to the recent increase in awareness of terrorist risks in the United States some data that may inform the national security value discussion is classified, while some is under development. The quantitative sources available use proxies for the value of fuel security such as military expenditures for safeguarding oil.

Ecosystem. The ecosystem category includes impacts to the natural environment caused by traditional electricity production. The subcategories identified include extraction and transport of fuel, global warming, silviculture, species diversity, and water quality. As in all categories, the ecosystem impacts overlap with impacts in other categories and with subcategories in this area. For example, global warming and insurance count some of the same values, while water quality and health impacts are related.

As shown in Exhibit 4, more sources were identified in the ecosystem category than in any other, however, most did not include quantitative data. Ecosystem has the potential to provide a high-dollar value because it includes the global warming subcategory. As with some other subcategories, additional estimates in global warming must be identified.

Human health. The environmental pollutants in this category can negatively affect human health. These particular pollutants were chosen for the following reasons: first, many of them are included on the Environmental Protection Agency's criteria pollutants and have been the major focus of most air quality regulations, second, a large quantity of data is available on each, and third, many studies have shown that these pollutants account for the majority of potential environmental damages.

This category includes more documents that contain quantitative data than the other categories. Data concentrations are especially high in the Nitrogen Oxides and Particulates categories, as the health effects of these pollutants are well established. One major issue with these estimates is their regional variability leading to very large range gaps. For example Nitrogen Oxides estimates in 2001 dollars range from $3.33/ton from replacing coal with natural gas, (Burtraw and Toman, 1998, p. 6) to $372,060 per ton in southern California (OTA, 1994, p. 25).

Human welfare. The human welfare category includes values that affect the population in many small ways. The subcategories identified include: horticulture damage, material damage, regulation costs, and visibility degradation. Quantitative data was available for material damage and visibility degradation.

"The Annualized Social Cost of Motor-Vehicle Use in the U.S., 1990-1991: Summary of Theory, Data, Methods, and Results" was initiated as an analysis of the impacts of motor vehicle pollution. The estimates of impacts by ton on material damage and visibility degradation are partially applicable to carbon-based power generation as well. In 2001 dollars, that document estimates $7 to $50 billion per year in visibility degradation damages (Delucchi, 1997, p. 55) and $0.5 to $11 billion per year in material damage (Delucchi, 1997, p. 55).

Next Steps

BCS is currently using the impact data presented in the Framework study to develop "Best Estimates" in selected categories and subcategories. These Best Estimates will be used to establish a more focused total value range; subsequently, the portion of the more focused value range that is applicable to DE will be established.

Each range will be evaluated and additional data will be collected when necessary. For each impact, an individual methodology may be developed. Each methodology will involve:

- An assessment of the available data sources,
- Identification of new data sources,
- Calculations to enable comparison between the quantitative data, and
- Selection of a best value including how that value relates to the current energy mix in the United States.

As the analysis continues, both the searchable database and the "Best Estimates" will be used as ongoing resources to evaluate the indirect benefits of DE. This data can be used to improve analysis of DE in U.S. Department of Energy evaluations, and in energy modeling applications. It could also be used to support state, local, and private analysis.

References

BCS, Incorporated. (2003). *Indirect Benefits of Distributed Energy Literature Database.* Available at: http://www.bcs-hq.com/der/indirect.

BCS, Incorporated. (2003). *Framework for Evaluating the Indirect Benefits of Distributed Energy.* Available at: http://www.bcs-hq.com/der/indirect.

Berry, J. E. (1998). *Power Generation and the Environment – a UK Perspective*. Available at: http://externe.jrc.es/reports.html. Framework ID-5.

Burtraw, Dallas and Michael A. Toman. (1998). *The Benefits of Reduced Air Pollutants in the U.S. from Greenhouse Gas Mitigation Policies*. Washington DC: Resources for the Future. Framework ID-128.

Congress of the United States, Office of Technology Assessment. (1994). *Studies of the Environmental Costs of Electricity*. Washington DC. Framework ID-001.

Delucchi, Mark A. (1997). *The Annualized Social Cost of Motor-Vehicle Use in the U.S., 1990-1991: Summary of Theory, Data, Methods, and Results*. Available at: http://www.fhwa.dot.gov/scalds. Framework ID-17.

Eto, Joseph, et al. (2001). *Scoping Study on Trends in the Economic Value of Electricity Reliability to the U.S. Economy*. Available at: http://eetd.lbl.gov/ea/EMS/reports. Framework ID-122.

Losman, Donald. (2001). *Economic Security, A National Security Folly*. Available at: http://www.cato.org/pubs/pas/pa409.pdf. Framwork ID-55.